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Talus slope in Franconia Notch. This colluvial material represents an extreme type of forested soil that can sustain trees, but conditions are quite variable according to position of the slope.

Forest Soils in the White Mountains:

WHAT ARE FOREST SOILS?[1]

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JUST as agricultural soils are the medium for producing our food crops, so forest soils are the medium for producing our timber crops. And just as the knowledge we have acquired about agricultural soils is largely responsible for our success in producing adequate food crops, so greater knowledge about forest soils will increase our ability to produce quality timber crops.

Trees and soils form an intimate association with one another. Not only do soils influence tree development, but trees influence soil development. Alteration of one affects the other.

Whatever the reason for one's interest in forests — be it conservation, protection, recreation, water production, wildlife management, or culture and harvesting of timber — the soils of the forest cannot be overlooked. Forests are understood best when both their above and below-ground portions are considered.

Forest Soil Defined

First, just what is a forest soil? To define a dynamic entity such as forest soil is not easy. A satisfactory definition

[1]This is the first of a series of articles about the nature and properties of forest soils and some of the effects of forest soils on tree growth.

should point out the essential distinguishing features of a forest soil, and it should be broad enough to include the variation in types; yet it should be narrow enough to exclude grassland, tundra and desert soils that also cover rather extensive areas of the earth's land masses.

The definition of a forest soil offered by S. A. Wilde[2] satisfies these requirements well. He has described forest soil as " . . . a portion of the earth's surface which serves as a medium for the sustenance of forest vegetation; it consists of mineral and organic matter permeated by varying amounts of water and air and inhabited by organisms; it exhibits peculiar characteristics acquired under the influence of the three [soil-forming] factors uncommon to other soils — forest litter, tree roots, and specific organisms whose existence depends upon the presence of forest vegetation."

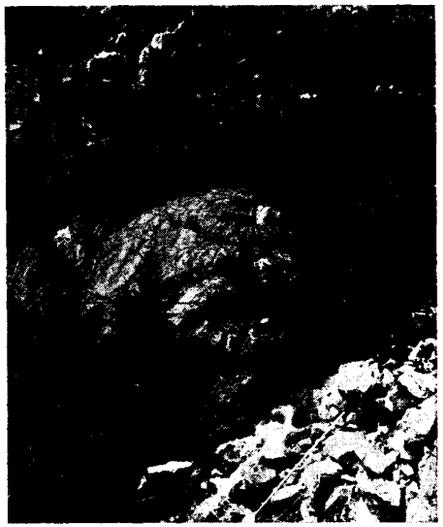
A key thought in this definition is the phrase, "the sustenance of forest vegetation." The definition places no qualification on the adequacy of the sustenance provided by the soil.

Variation in Forest Soils

Various kinds of forest soils occur in the White Mountains of New Hampshire. Many persons who have planted shade trees in their yards or Christmas trees in their woodlots quite naturally think of soil as something that can be worked with a shovel, hoe, and rake. But not all forest soils are of this type. Forest soils vary greatly in their ability to sustain tree growth. Several kinds of soils that sustain trees can be observed from the main highways while driving through the White Mountains, or by moving a short way into the adjoining forests.

Rock Outcrop Soils

These generally occur on mountainous ridges or steep slopes, and occasionally at lower elevations where glacial action has scoured to bedrock. A good example can be seen in Crawford Notch,



Slow-growing spruce forests have developed on these bare rock outcrops in Crawford Notch. Notice that there is very little weathered mineral material or accumulation of organic matter.

where dwarf spruce-fur forests maintain a marginal existence on rocky ledges.

On such soils there is practically no accumulation of weathered mineral material. Organic material collects in crevices and fissures in the rock, but does not form a continuous cover. It is in these cracks and crevices that tree roots develop and are able to extract some nutrients from the small deposits of organic material, from the solutes in rain and meltwater which flow down and over the ledges, and by direct extraction from solid minerals. This last is commonly referred to as "solid-phase feeding." Though not well understood, solid-phase feeding by tree roots is apparently aided by symbiotic root fungi.

Rock outcrop soils are considered to be xerophytic; that is, dry sites, since there is little soil material to absorb and retain water from precipitation. However, this situation is offset somewhat by nightly condensation of moisture in rock crevices.

Colluvial Soils

Colluvium is the unsorted or slightly sorted material that accumulates at the

[2]Wilde, S. A. *Forest Soils.* The Ronald Press Co., New York. 1958.

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magnesium, sulfur, iron, copper, maganese, zinc, boron, and molybdenum. The first six (microelements) are required by trees in greater amounts than the last six (microelements). But the amount of an element required is not an indication of its importance. All twelve are necessary. Absence of any one will seriously retard tree development and affect health. Nitrogen is unique among nutrient elements, for while 78 percent of our atmosphere is nitrogen, the sole source of supply is from soil. Less than optimum tree development occurs when one or several of these nutrients is deficient in the soil. Outward signs of such malnutrition are frequently not apparent. It is the job of forest soil scientists to detect such malnutrition, understand the causes, and suggest remedies.

Fouth, soil aeration is important because the oxygen in soil air permits respiration in tree roots. Respiration is the breaking down of foods, with a subsequent release of energy. Waterlogged soils, which tend to have low oxygen content, may therefore restrict tree growth even though other factors are favorable.

Fifth, microorganisms of the soil are beneficial to trees in several ways. They help to break down organic materials, which releases nutrients in a form available to trees. An example is the soil bacteria that convert organically bound nitrogen into usable inorganic ammonium and nitrate. Other microscopic organisms, soil fungi, form a symbiotic relation with tree roots, which increases their ability to absorb essential nutrients.

In summary: the nature and properties of forest soils and their effects on trees are complex and variable. Our present knowledge is meagre. Awareness of these situations and increased study of forest soils is needed to preserve, protect, and manage our forests more wisely in the future than we have in the past. In this way, forests can be a continuing source of wildlife, wood products, water, recreation, and appeal to man's aesthetic sense.

base of steep slopes under the influence of gravity. It is composed primarily of assorted sizes of rock fragments with more incorporation of finer materials at lower elevations. The coarser material is called talus. Such talus slopes are visible from the highway in Franconia Notch.

Forests develop best at the base of these slopes, and poorly or not at all higher up on the talus. These soils are relatively unstable as a result of gravity, frost action, and spring meltwaters; so the margin of forest advance changes frequently as conditions are favorable or unfavorable.

Soils in these areas represent a continuum of conditions from higher to lower elevations. The coarse, unvegetated talus grades into mixtures of smaller, weathered, mineral materials and accumulations of organic matter at lower elevations. Finer-textured soil washed into the area at lower elevations; and buried organic matter, while presenting a hodgepodge of materials, will support good growth of trees.

Shallow Organic Soils over Bedrock

The progressive colonization of bedrock at higher elevations by a succession of vegetational types has resulted in establishment of forests on what are essentially shallow organic soils. The forest floor is continuous and bound together by the proliferation of tree roots. You can see this type of forest soil by taking a ride to the top of Wildcat Mountain in a gondola.

The forest cover here consists of spruce, fir, and birch. Trees at the summit are short and stunted, but density of new seedlings is great. You can pull the humus material aside to expose solid rock beneath and see that there is little or no development of mineral soil.

The humus generally provides an adequate source of moisture and nutrients for good growth, but the trees suffer from competition and exposure. The organic layer persists because deposition exceeds decomposition in the climatic conditions of the area.

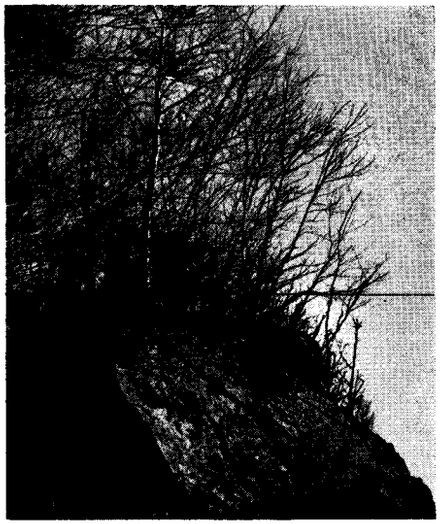
Peat Soils

Peat soils consist largely of organic residues from partly decomposed leaves, twigs, bark, wood, and herbaceous plants. Peat soils originate generally in depressions with poor drainage, anerobic conditions (absence of free oxygen), and low temperature. Depth of peat varies greatly, and can accumulate to 10 feet or more.

Peat soils are generally very acid in the surface layers; but acidity usually decreases with depth and may approach neutrality at the interface or organic and underlying mineral soil. The mineral soil beneath is frequently water-saturated; and reducing conditions (low oxygen) produce a gray to olive-drab, sticky soil that is called gley. Poor drainage permits accumulation of basic elements in gley, which accounts for neutral reactions (that is, only slightly acidic).

The nutrient status of peat soils is complex, but generally they are low in potassium and phosphorus, high in calcium and sulfur, and frequently deficient in one or several of the microelements such as copper and zinc.

Spruce trees growing in a sphagnum bog in White Lake State Park, West Ossipee. This type of forest soil is composed almost entirely of decomposed organic material.



Poorly developed beech and birch trees are sustained on this bare rock outcrop in Franconia Notch.

Forests that occur on peat soils are variable. Conifers such as spruce, fir, pine, and larch, and the deciduous red maple are commonly found on such soils. A small area of forested peat soil supporting white birch, white pine, balsam fir, and black cherry can be seen on the Northeastern Forest Experiment Station's experimental forest in Bartlett, New Hampshire.

A particularly interesting type of peat soil is sphagnum or quaking bogs. They are extremely acidic, and forests that grow on them are composed primarily of black spruce and larch.

Outwash and Till Soils

These are our most important forest soils in terms of area occupied and the commercially valuable forests they support. Both soils are the results of glaciation. They can be seen in many roadcuts along the State's highways.

Outwash is a general term that includes all the materials spread out, sorted, and deposited below the glacier by streams of meltwater. Nearly 10 percent of the State is covered by outwash soils. Topography is generally level to gently sloping. In New Hampshire, size of mineral material ranges from coarse gravel to fine sands and some silt, with little or no clay. The important feature of outwash is the sorting action of meltwater, which results in the deposition of materials in strata or layers according to size.

Much of southeastern New Hampshire is covered by glacial outwash that supports stands of oaks and pines, either in mixture or separately. Forest growth on outwash soils varies greatly according to depth, texture, mineralogy, degree of weathering, and incorporation of organic matter. White pine is the most productive forest type on such soils.

Glacial *till* was deposited directly by the ice, with little transportation by water. Till soils are not laid down in strata, but are unconsolidated deposits with a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and even enormous boulders. Indeed, fields of these boulders are common. Glacial till covers about 83 percent of the State.

Forest till soils vary considerably in observable features and properties. Depths range to 10 feet or more. Textures are primarily coarse to fine sands. Some till soils are permeable throughout, while others are underlain by compact platy layers that either impede or completely restrict downward movement of water. Aeration is generally good.

Till soils are low in plant nutrients, especially phosphorus and some microelements such as boron. Those derived from schist may have a slightly higher base (calcium and magnesium) content than those formed from granite.

Till soils support several different forest communities. Among these are red and white pines and red oaks, which frequent south-facing slopes at lower elevations. North-facing slopes support more northern hardwoods, birch, beech, and maple) at low elevations, with or without hemlock. Mixtures of hardwoods and spruce-fir prevail at middle elevations, and mostly spruce-fir prevails at higher elevations. These are generalizations and there are, of course, many exceptions.

Forest soils of glacial till and outwash belong to the order of zonal soils, which simply means that several distinct zones or horizons, formed under the influence of climate and vegetation, are perceptible. These horizons are variously colored. The surface soil is dark to light gray, the upper subsoil is brown to reddish-brown, and the lower subsoil is yellow and grades to buff or olive-drab with increasing depth.

In turn, two great soil groups in this order are recognized — podzols and brown podzolics. These two soil groups develop in humid temperate regions under forest vegetation. The forest litter is generally acidic; and in areas of much rainfall (in our area about 50 inches per year) these soils are thoroughly leached. Hence soluble carbonates are removed while iron, aluminum, and silicate clays accumulate in the sub-soil.

Podzols show the extremes of this type of weathering, and brown podzolics less so. Further detailed description for this type of soil genesis will be presented in a later article. Meanwhile, it should be clearly understood that these are the two great soil groups with which the forest and land managers in New Hampshire will be most concerned; and about which much more knowledge is needed with regard to their formation, properties, and effects on tree development.

Importance of Forest Soil to Trees

It is widely believed that trees are not very demanding of the soil, and that, given adequate water and sunlight, they will grow satisfactorily with little attention. This viewpoint is changing rapidly as a result of research in forest soils over the past two decades. We are finding that soil-fertility conditions are prohibiting optimum growth and health of trees in many areas.

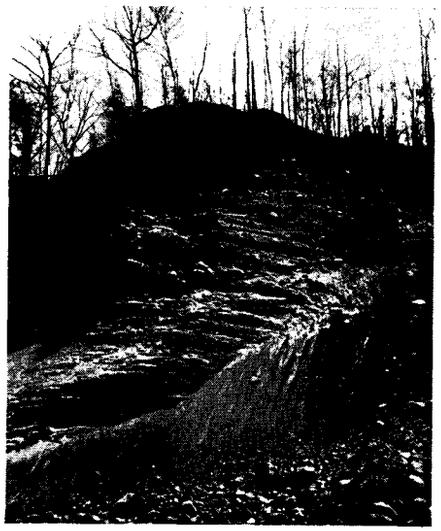
Efforts in research are now being directed toward means of assessing forest soil productivity, and methods to correct adverse soil conditions. However, the pressure of economic considerations often precludes the application of soil-management practices that research has indicated would be helpful. The situation is changing, and with new knowledge comes growing awareness and greater interest in the whole subject of forest soils.

Very briefly, forest soils are important to trees for the following reasons.

First, soils provide the physical support or anchorage for trees. The mound-and-depression topography of our mountainous forest soils is mute testimony to the prevalence of tree losses from windthrow or inadequate anchorage. Knowledgeable soil management offers possibilities for reducing such losses.

Second, soil moisture is the primary source of water for tree use. Water is taken up in transpiration, and hydrogen in water is combined with carbon dioxide by the process of photosynthesis in tree leaves to produce the food necessary for growth and other metabolic processes.

Third, nutrients provide an additional dozen reasons for the importance of soils to forests. Namely, they are nitrogen, phosphorus, potassium, calcium,



Deep mineral soil of glacial origin (alongside Route 302 in Hart's Location) supporting forests of birch, beech, and maple. Note how soil material of all sizes is mixed together with little sorting.